

# Interplanetary Alfvénic Turbulence: The Need for Verification and Modeling

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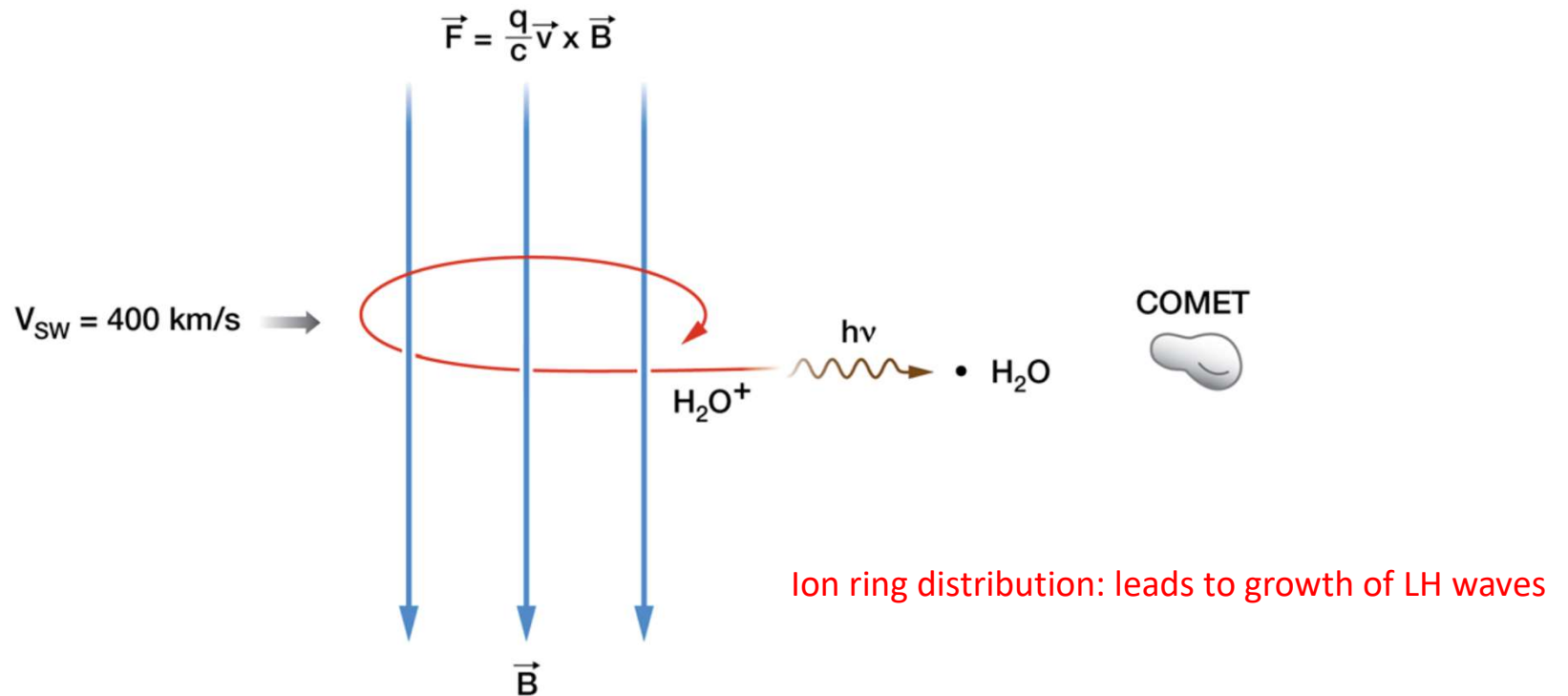
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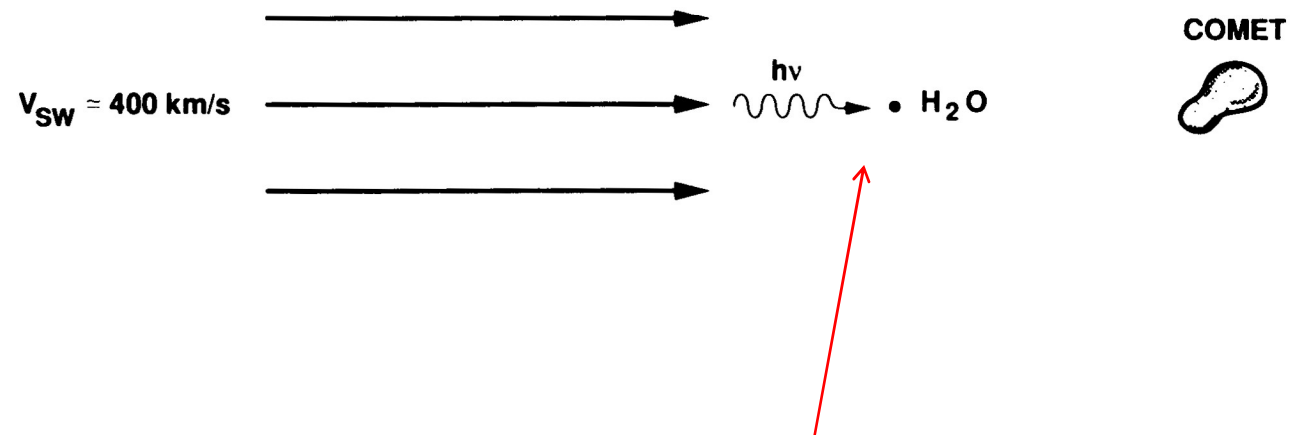


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# Some Background on Nonlinear Waves: A Cometary Example

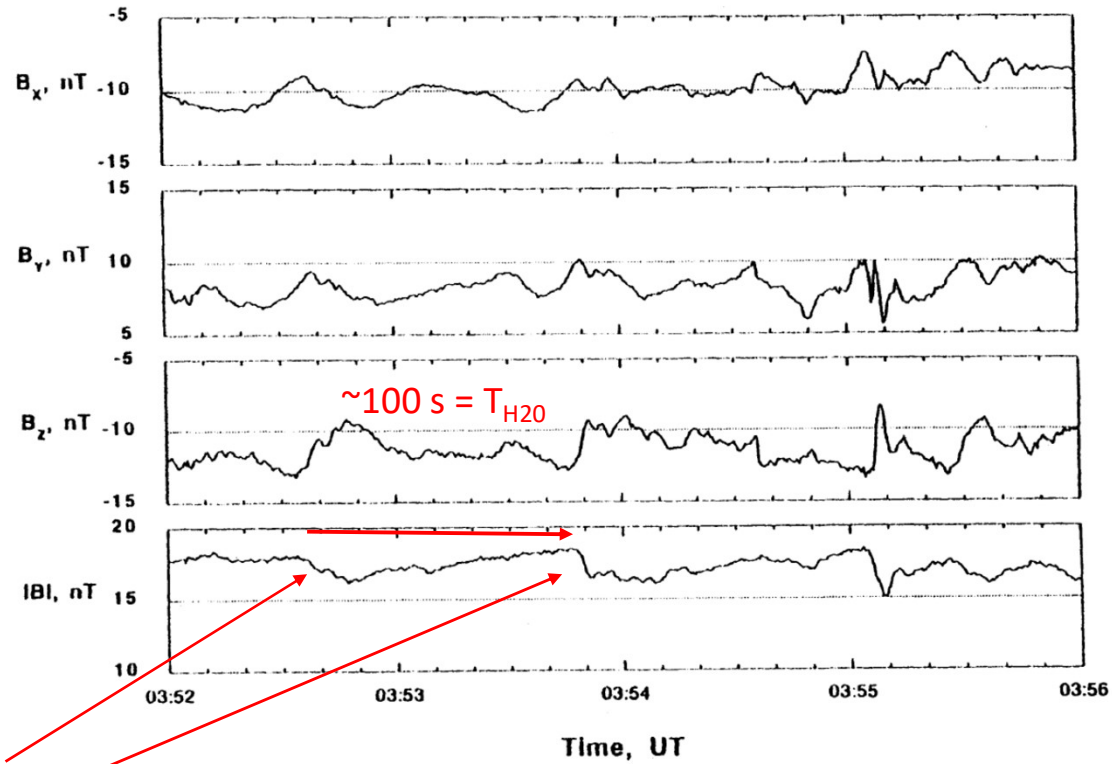


# ION BEAM INSTABILITY



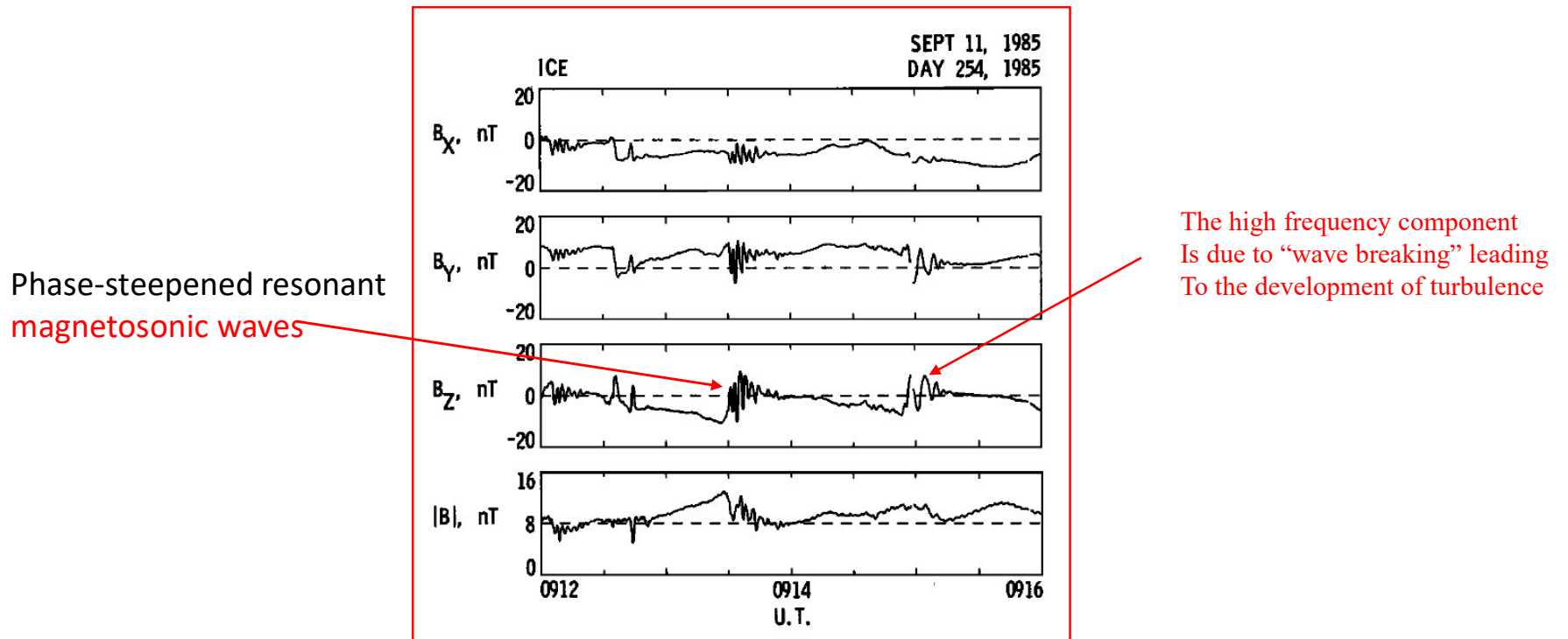
This distribution function (a high velocity beam) leads to growth of **right-hand magnetosonic waves**, then mass loading

# Magnetosonic Waves Start Out Like Waves At the Beach

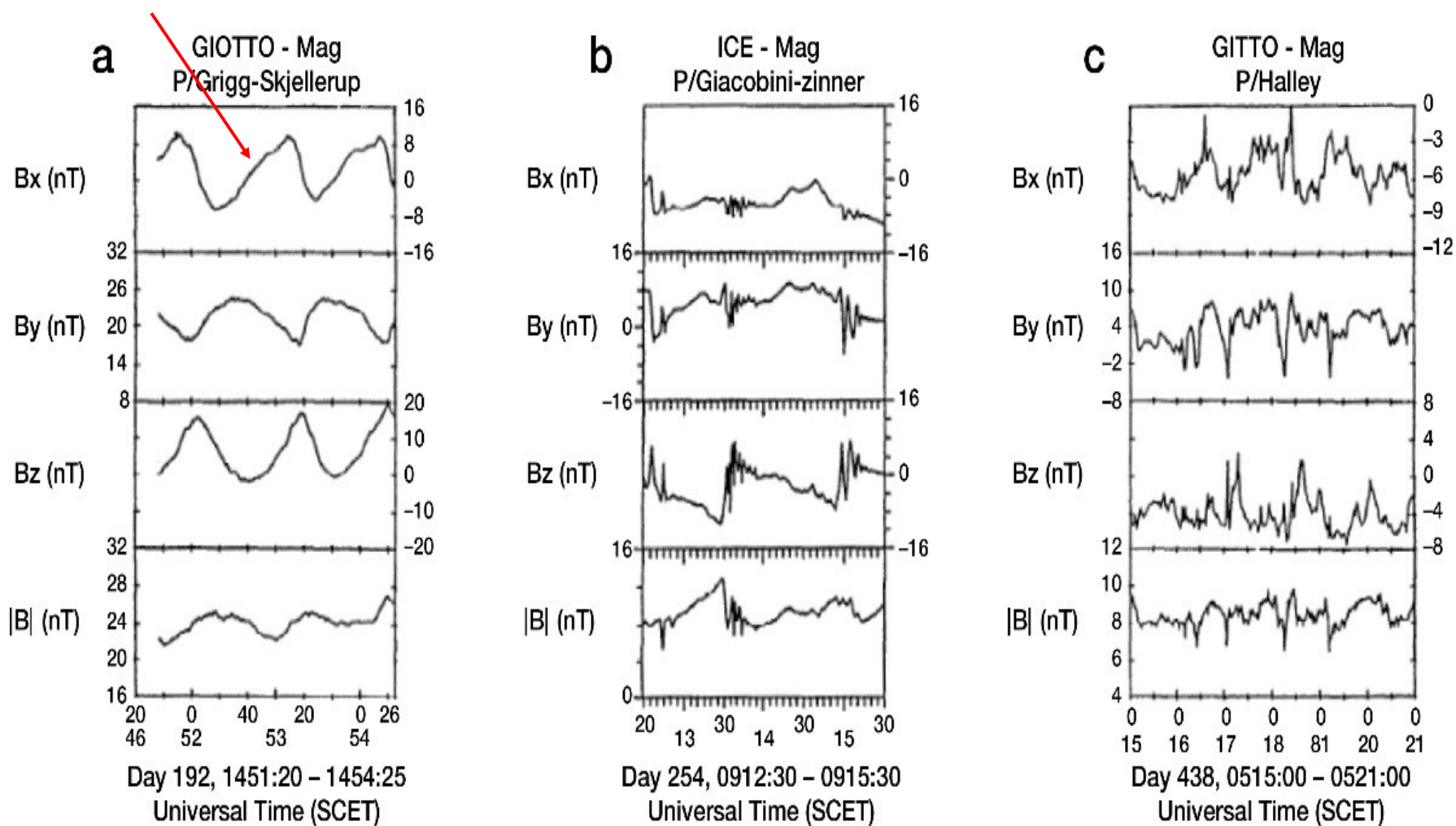


"Beach-like waves"

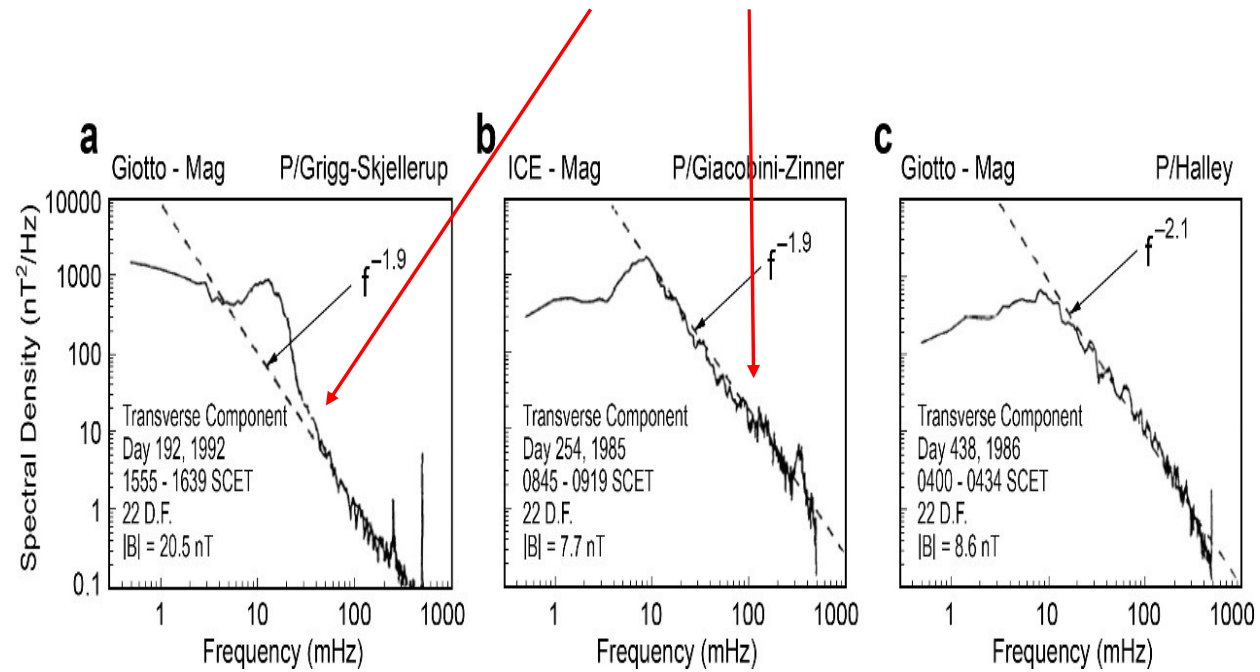
## Then Magnetosonic Waves “Break” Forming High Frequency Whistlers at Their Fronts



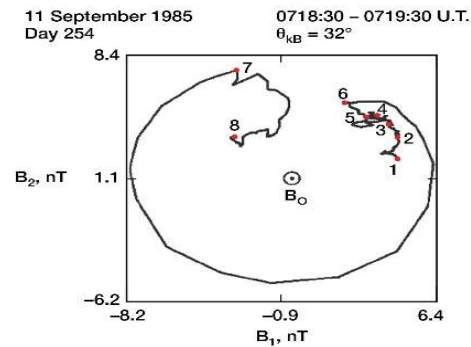
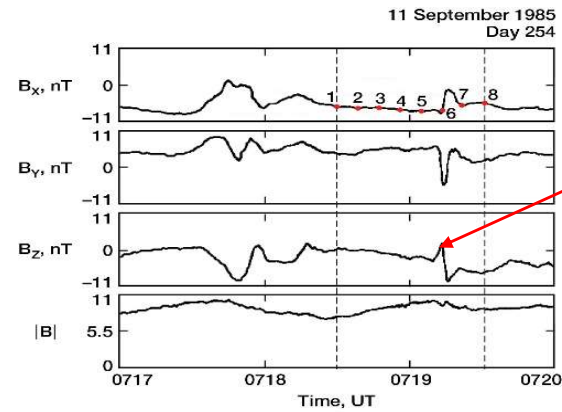
## Even nonlinear LH waves phase steepen



However, Independent of Wave Helicity, Turbulence Forms Nice Power Law Spectra



Phase-Steepened Magnetosonic Waves: All of Circular Polarization Occurs at One Edge  
(This is a Form of “Wave Breaking” and “Period Doubling” at the Same Time)



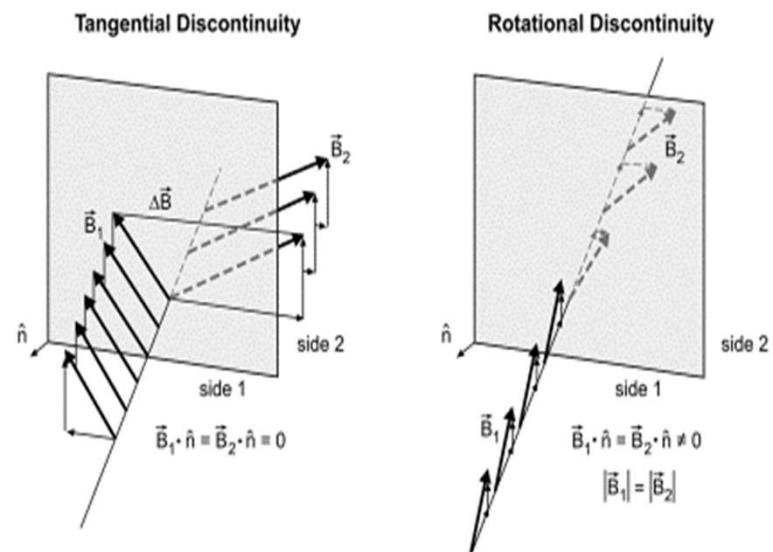


# Interplanetary Alfvénic Turbulence

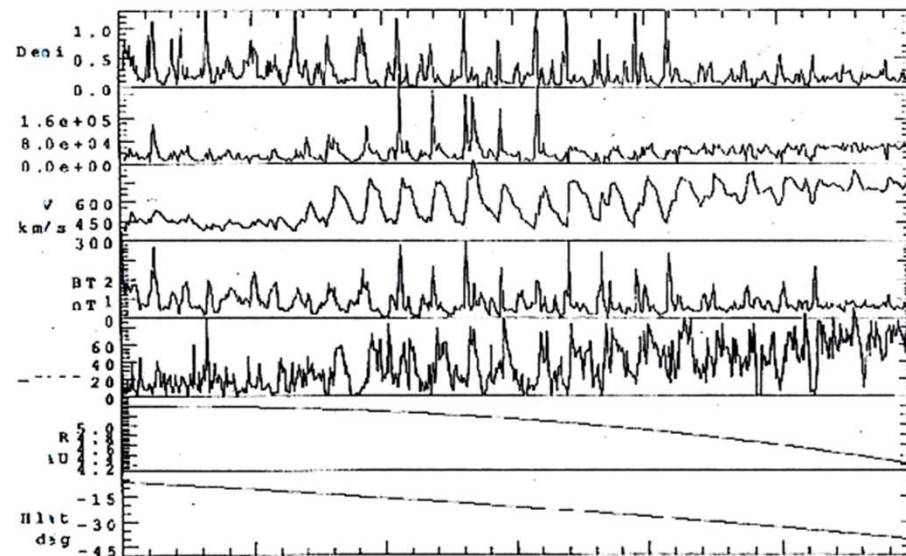
Most theories of Alfvénic turbulence formation assume that **wave-wave interactions lead wave cascading**. However there is little or no direct evidence for this.

The evidence presented is from **Elsässer variable analysis** results. However **static structures** present in the interplanetary medium could be misinterpreted as equal forward/backward propagating waves.

# Discontinuities Detected in the Solar Wind



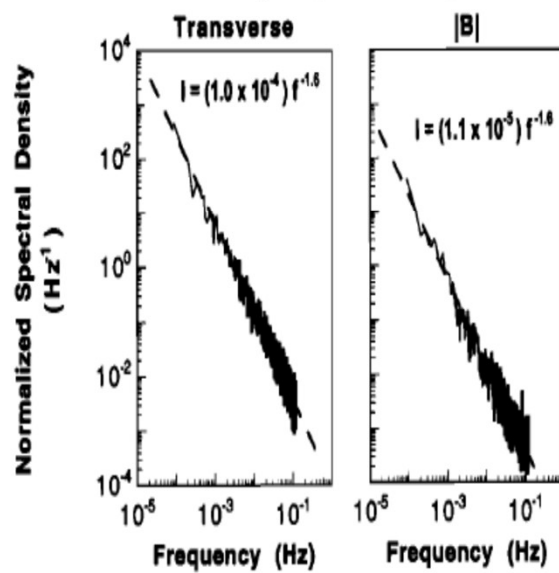
# Number of Directional Discontinuities As A Function of Heliolatitude



← #DDs  
Decreasing Heliolatitude

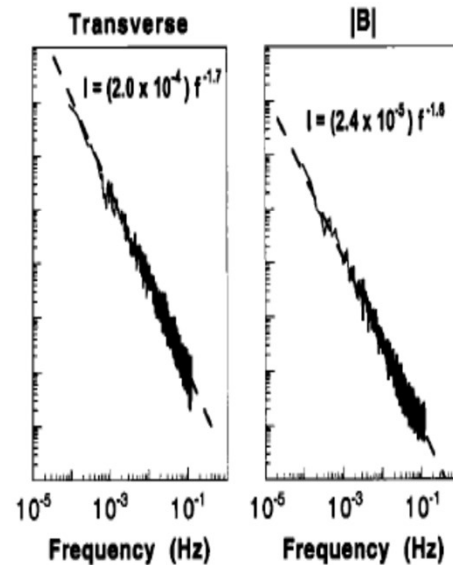
**Heliographic Latitude = -1.9°**  
**Distance From Sun = 1.8 AU**

1991 Day 020, 00:00 - 022, 00:00

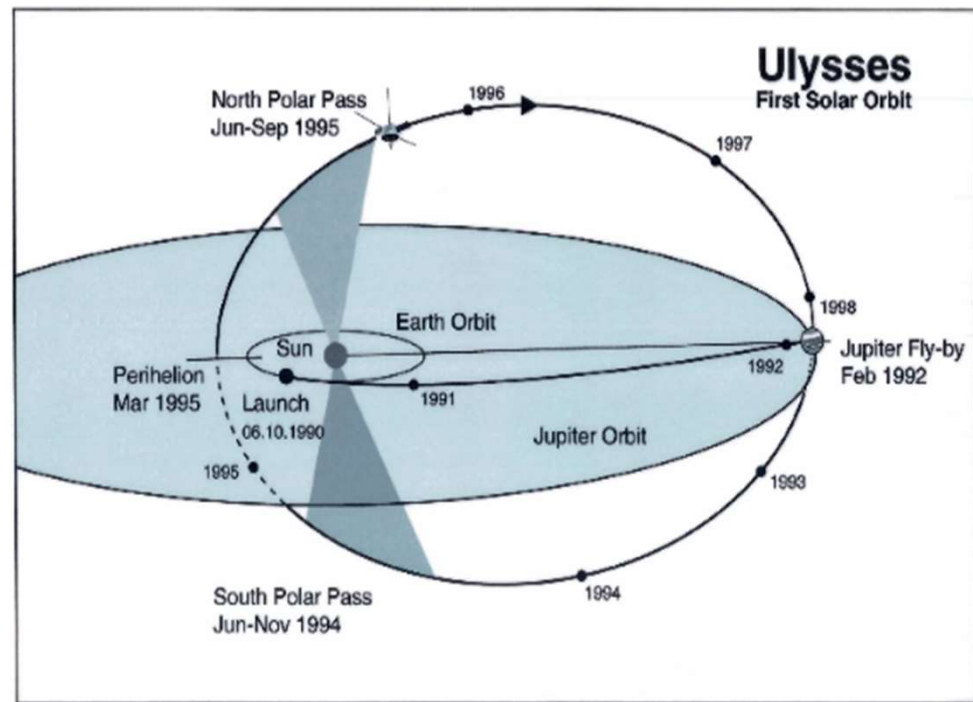


**Heliographic Latitude = -79°**  
**Distance From Sun = 2.4 AU**

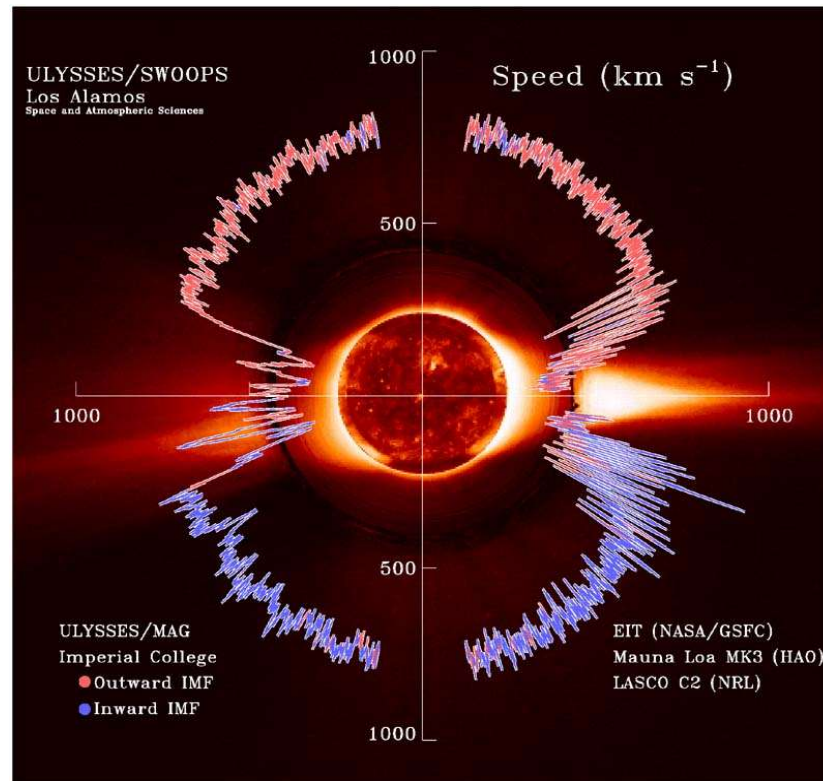
1994 Day 238, 00:00 - 240, 00:00



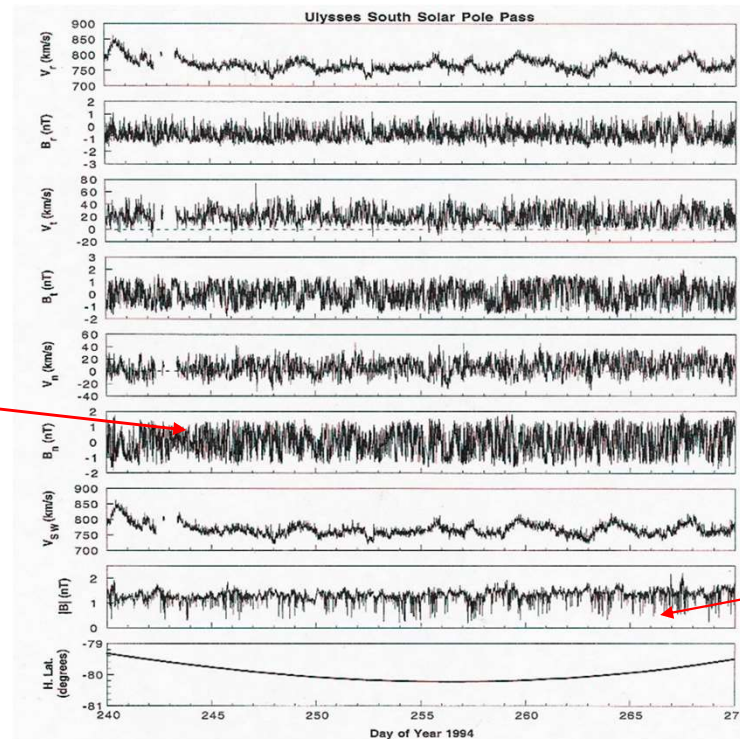
## The First Ulysses Pass Over the Solar Poles Occurred in a Declining Phase of the Solar Cycle



## Ulysses Solar Wind Speeds: High Speed Streams from Polar Coronal Holes



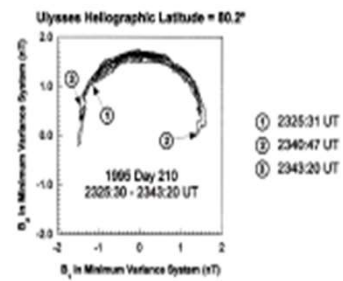
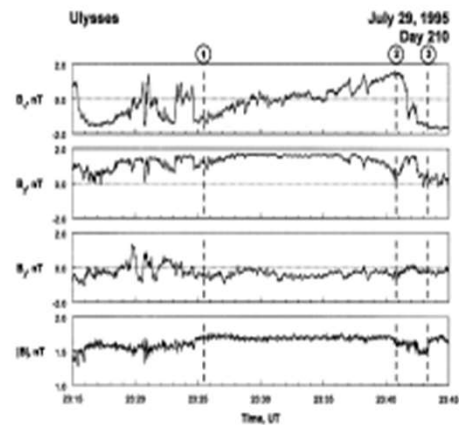
# Alfvén Waves and MDs Over the South Solar Magnetic Pole



Nonlinear  $\Delta B/B \sim 1$  to 2 Alfvén waves

Magnetic Decreases (MDs)

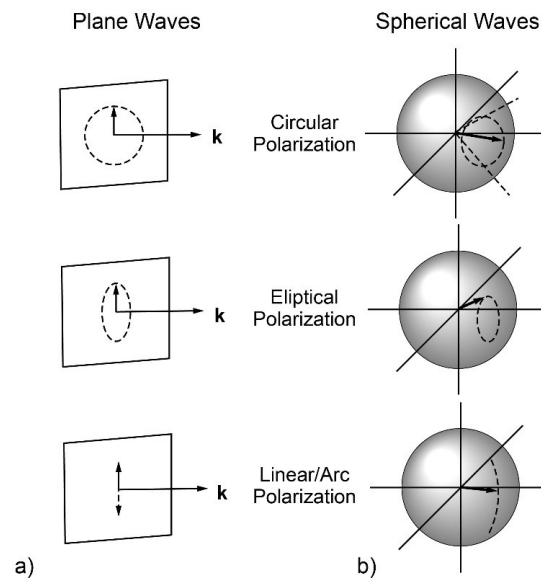
This Is What a Single Alfvén Wave Cycle Looks like:  
“Arc Polarization”



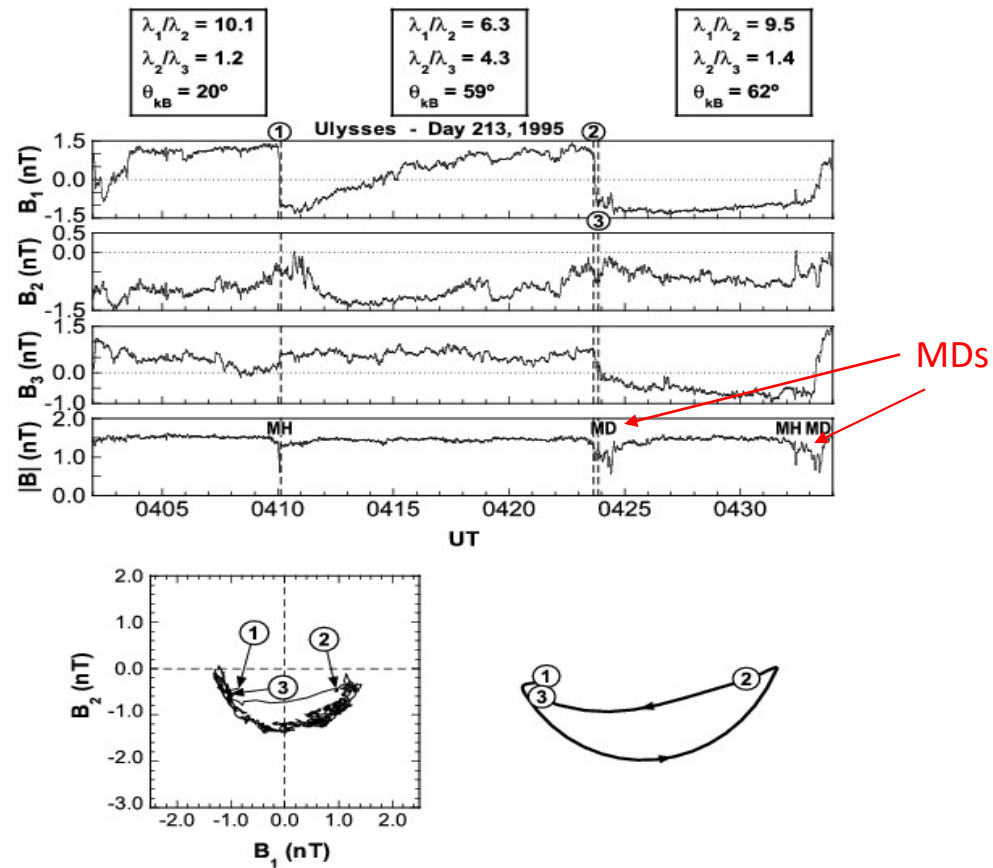


# What Does Arc Polarization Mean?

## Analogy of Spherical Waves to Plane Waves



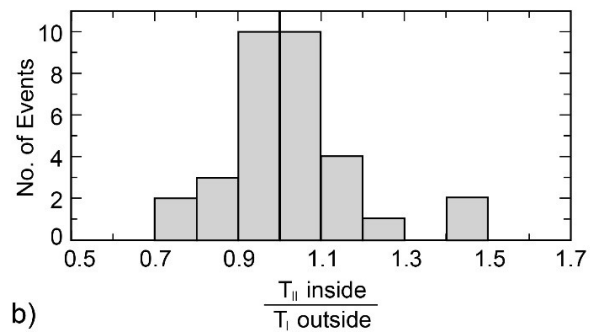
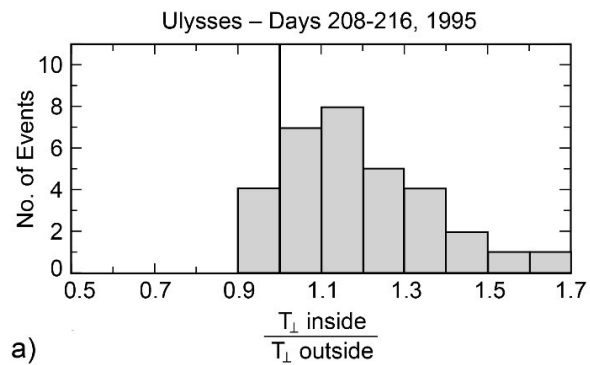
# Three Alfvén Wave Cycles: MDs at the Edges



# Solar Wind Protons inside MDs Have Been Heated.

(Alfvén Wave Kinetic Dissipation by the Ponderomotive Force?)

Distribution of Protons  $T_{\text{inside MD}}/T_{\text{outside MD}}$  Ratios  
Ulysses North Pole



# Conclusions

Interplanetary Alfvén waves in high speed solar wind streams phase-steepen into “arc polarized” waves. The wave splits into a rotational discontinuity and trailing elongated portion. The former is a form of “wave breaking” and the latter that of “period doubling”. Both wave breaking and period doubling occur at the same time.

This could be the essence for the formation of plasma turbulence in interplanetary space.

Magnetic Decreases (MDs) are located at the phase-steepened edges of the Alfvén waves. These could be created by the kinetic dissipation of the Alfvén waves.

MDs are static structures and could be misinterpreted (by Elsässer variable analysis) as forward and backward propagating Alfvén waves.

The large solar wind data sets obtained from the Solar Orbiter and Parker Solar Probe missions could be used to test these ideas.

Models of the kinetic evolution of Alfvén waves are needed to understand how further evolution may or may not evolve to a fully turbulent state.

THANK YOU FOR YOUR KIND ATTENTION